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Study of Influence of Land Cover on Urban Heat Islands in Pune Using Remote Sensing

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ABSTRACT : *Urban centres with large populations tend to create microclimates different from that of the surrounding region which is called as urban heat island effect. (UHI) High-rise, high density built areas and reduction in vegetation provides multiple surfaces for the reflection of direct and indirect solar radiation as well as absorption & storage of heat. The cities are becoming complex character consisting of different surface materials of low albedo and with lack of vegetative cover. The aim of the study is to find out whether change in land cover in Pune contributes to the change in land surface temperature. The objective is to understand role & influence of various land covers to achieve better micro-climate in urban area. The method used is Remote sensing application IDRISI-Andes for prediction of temperature variations associated with different land cover types. To assess the thermal environment (UHI) of Pune for 1999 and 2006 the data is derived from LANDSAT images.*

There has been a 32.68% increase in built up area from 1999 to 2006 leading to a sharp decline of 10% area in agriculture & 21.91% area in barren land in mostly attributing to intense urbanisation process. Vegetation has decreased by 10% from 1999 to 2006. There has been a $1^{O}C$ to $4^{O}C$ rise in surface temperature in Pune since 1999 to 2006. Suburbs are heating up much faster than the inner city, due to the construction boom.

Keywords – *land cover, microclimates, remote sensing, temperature, UHI.*

I. INTRODUCTION

1.1Background-Urbanization & climate

Urbanization has a dynamic relationship with the physical environment. Urbanization has direct impact on the spatial structure of the city, which in turn results in the dramatic change of the overall immediate environment. Rapid urbanization, often neglecting design issues related to urban climate are likely to increase levels of discomfort in cities. The cities are becoming complex character consisting of different surface materials of low albedo and with lack of vegetative cover.

1.1 The Urban Heat Island-UHI

An Urban Heat Island (UHI) is a metropolitan area which is significantly warmer than its surrounding rural areas, i.e. urban air and surface temperatures that are higher than nearby rural areas. The concentration of human activities in urban areas creates an "island" of heat surrounded by a "sea" of cooler rural areas called the "urban heat island". [1] The main cause of the UHI is modification of the land surface by urban development which uses materials which effectively retain heat. An UHI is created when naturally vegetated surfaces – e.g. grass and trees are replaced with non-reflective, impervious surfaces that absorb a high percentage of incoming solar radiation. UHI has become more and more significant during the last 50 years, due to urban growth and increase in energy consumption in urban areas. [2]

1.2 Significance of topic

Approximately half of the world's population lives in cities, and this value is expected to increase to 61% by 2030. India is increasingly becoming urban. According to the 2001 Census, 27.8% of the urban population resides in cities, compared with 25.5% in 1990. The Urban population is expected to rise to around 40% by 2020. City growth and urban development are inevitable phenomenon of the 21st century, hence there is a need to explore the causes and peculiarities of the UHIE and propose solutions to the problem.

II. METHODOLOGY

2.1 Steps are as follows

1. Study LULC & change in ST in Pune for 1999 & 2006. 2. Assessment of spatial and temporal changes. From thermal bands actually derive the surface temperatures. 3. Identify heat pockets or zones using Remote sensing-RS data and techniques. 4. Analysis of all to find out relationship between LC and ST (UHI). Studies on the Correlation between LULC and UHI Effect

2.2 Approach to UHI (heat pockets) identification-Geospatial/ Remote Sensing-RS analysis

The study of UHI has been largely dependent on RS data and land surface temperature (LST) derived from the satellite data. IDRISI is integrated GIS and RS software for the analysis and display of digital geospatial information. Landsat can offer detailed mapping of Pune City's UHI. RS data which is freely

available on GLCF website used for the study is: Landsat TM (1992), Landsat ETM+ (1999), Landsat ETM+ (2006), Band 2- visible green, Band 3- visible red, Band 4- near infrared, Band 6- thermal infrared. (Land Sat data downloaded from GLCF website http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp, accessed on Tuesday, January 10, 2012, 10:23pm) [3]

2.3 Research Procedure using IDRISI software

1. Preprocessing- Remotely sensed data is not free from internal and external errors such as radiometric and geometric distortion. "Therefore, it is necessary to preprocess the remotely sensed data prior to actually. 2. Image Enhancement-The goal of image enhancement is to improve the visual interpretability of an image by increasing the apparent distinction between the features in the scene (Lillesand & Kiefer., 1994). Cropping of the study area is done here. 3. Colour Composite-Colour composite is a process, where we used a combination of band and that combining band gives more information. However there are two types of composites- True Colour Composite (TCC) & False Colour Composite (FCC)-Standard composite (432) & Non standard composite (452, 453, 457). FCC 432 will be used because of benefit and several informations. 4.Supervised Image Classification-Categorization of pixels based on reflectance into different land cover classes. Generally there are several methods for supervised classification. The maximum likelihood is more suitable for LULC classification. In supervised classification, the pixel categorisation process is done by specifying the numerical descriptors of the various LC types present in a scene. It involves (i) training, (ii) classification and (iii) output. 5. Reclassification- Reclassification for land cover is needed because of distortion and finally we will get the land cover map. 6. Change Detection - Determine the changes from images taken at different times of the same area 7. Transformation-Derivation of LST-The corresponding temperatures for all data derived from ETM thermal bands (6.1) were converted to degree Celsius. [4]

III. ANALYSIS OF DATA & FINDINGS

3.1 Findings Observations in land cover changes- from Remote Sensing data techniques

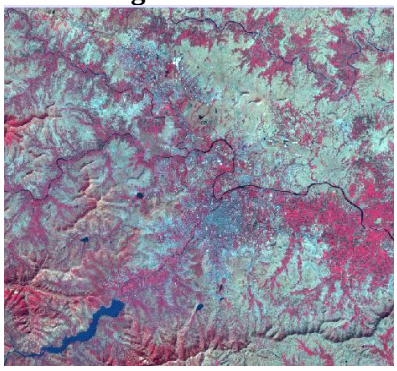

Fig 1: FCC-04 December 1992

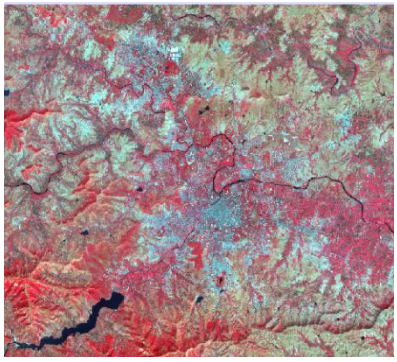

Fig 2: FCC-14 November1999

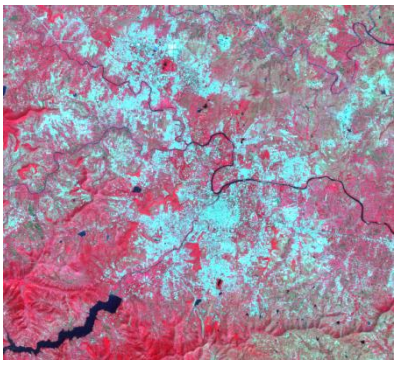

Fig 3: FCC-16 October 2006

From the classified raster maps shown above, 8 urban classes ware extracted and converted to vector representation for computation of precise area in Sqkm. There has been urban expansion, industrialization and declining green cover. The city has already engulfed vast tract of the surrounding rural land by the dramatic sprawl and LUCC since 1992. Out of total area 1337.58 Sqkm, there is change in land cover in 778.212 Sqkm (58.18%) of area & in remaining 559.36 Sqkm (41.82%) there is no change in land cover. The growth poles are towards NW, S and SE of the city indicating the intense urbanization process due to growth agents like setting up of IT corridors, industrial units, etc. Newly built up areas in these regions consisted of maximum number of small-scale industries, IT companies, multi-storeyed building and private houses that came up. The growth in northern direction can be attributed to the Airport at Lohegaon, encouraging other commercial and residential hubs. The southern part of the city is experiencing new residential and commercial layouts and the south & west part of the city outgrowth corresponds to the development along with the Bangalore-Pune National Highway 4 & National Highway 9.

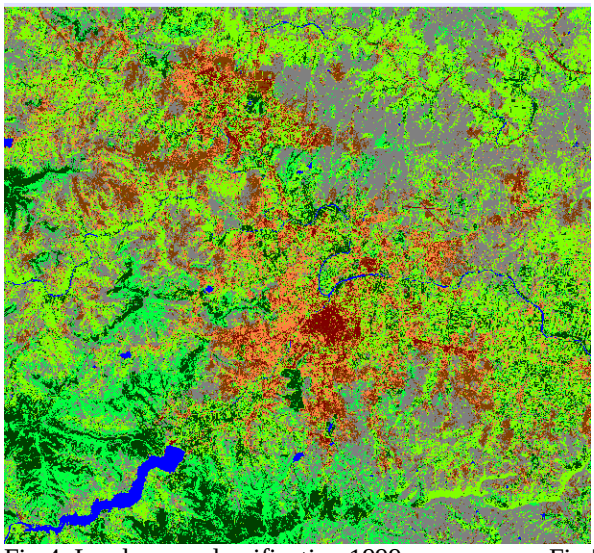

Fig 4: Land cover classification 1999

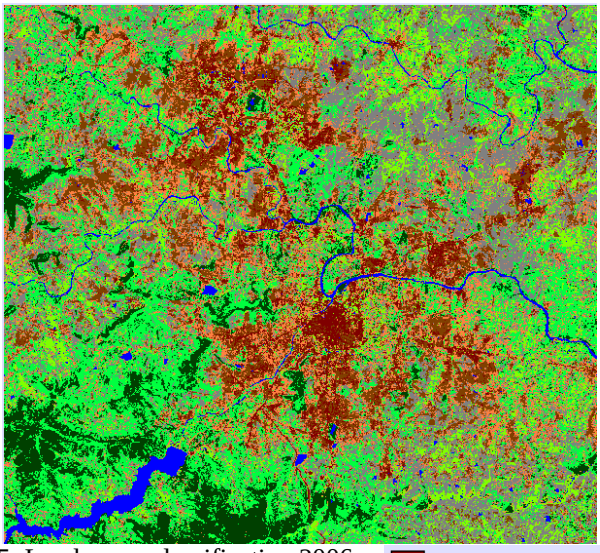

Fig 5: Land cover classification 2006

From the pie charts Fig 6 & 7, The area of settlement in 1999 was about 271.33 sq.km (20%), while in the year 2006 the settlement drastically increased by 437.07sq.km (33%). This change was mainly due to expansion of urban areas in the form of newly developed, area in the pre-existing agricultural and barren land. There has been a 33 % increase in built up area from 1999 to 2006 leading to a sharp decline of 10% area in agriculture (crop land and plantation) & 21.91 % area in barren land in mostly attributing to intense urbanisation process. The total agriculture land in 1999 was about 360.71 sq.km (27%). During the last 7 years total area of the agriculture land was decreased about 132.53 sq.km. The agricultural land was mainly converted as settlement. Because of the development of the city, the land value has escalated and caused the conversion of agricultural land to settlement. In 2006, it was reduced to sq.km (10 %).

3.2 Structure of the UHI- Thermal Zones within the Urban Area-Analysis of LST Variation of LULC Types

Daytime mean LST of LULC types in the metropolitan area decreases from industrial, high-density residential commercial, pavement roads, low-density residential commercial, rural residential and vegetation to water. The spatial pattern of an idealized UHI is one in which the temperature decreases outward from a city center. The minimum and maximum temperature from Landsat ETM+ data of 1999 was 7.28 and 32.71 with a while for 2006 ETM+ data was 13.57 and 24.35. It is clear that urban areas that include commercial, industrial and residential land exhibited the highest temperature followed by open ground. Figure shows that relatively warm regions extend in the south east–north west direction, and relatively cold regions are located near Khadakwasla. UHI centers (over 20.18°C) are located in main industrial zones. Average remotely-sensed surface temperatures range from 20-24ºC. PCMC is the hottest case study area. The (Cool spots) coolest areas are, Khadakwasla, and nearby Vegetated areas which are between 14–17ºC. There has been a 1^{O}C to 6^{O}C rise in LST in Pune since 1999 to 2006.

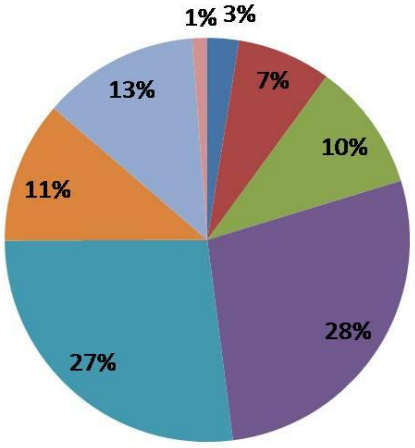

Fig 6: Land cover in 1999

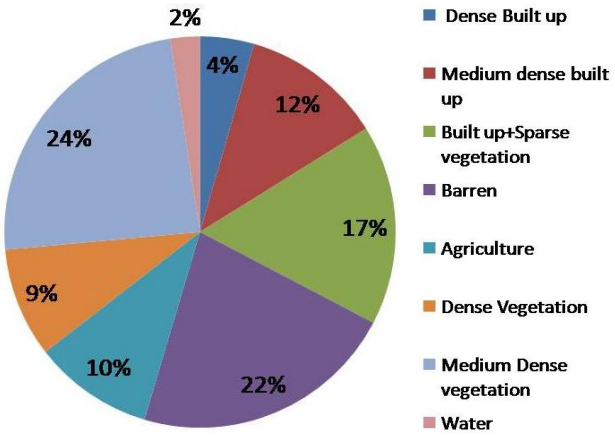

Fig 7: Land cover in 2006

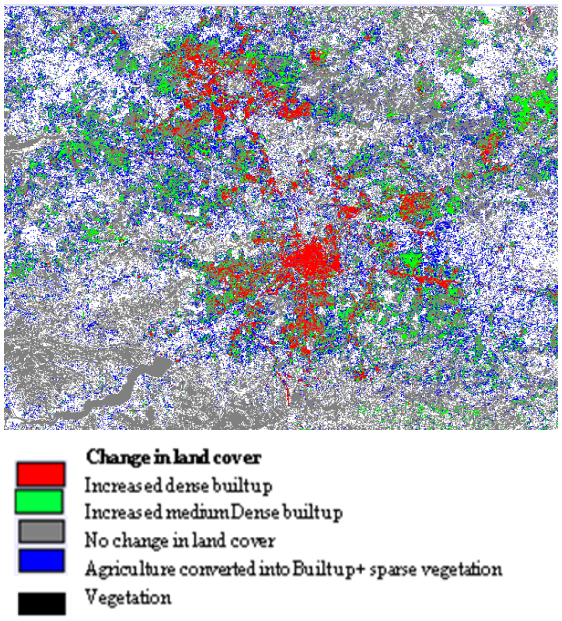

Fig 8: Spatial land cover Change

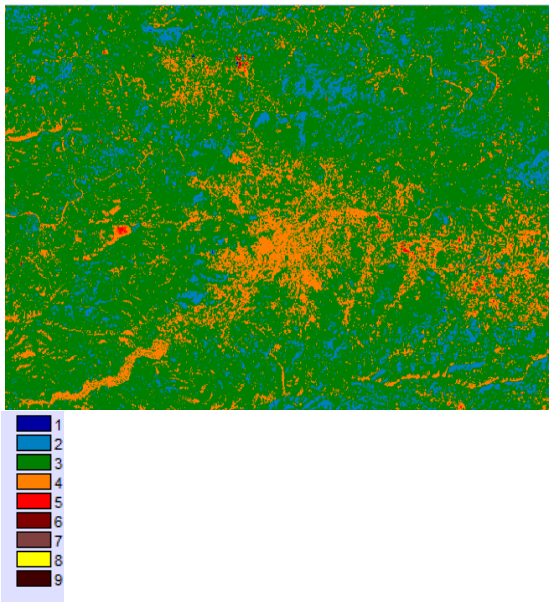

Fig 9: ST Comparison (99 Vs '06)

3.3 Cross classification & Comparison between LC & LST- Analysis of LST & Land Use Patterns

It was found that maximum temperatures were recorded over areas with a higher percentage of urbanization/building cover, the opposite was found for areas with a higher percentage of green cover. Of all the land use types studied built-up areas showed the highest average temperatures. Daytime mean LST of LULC types in the metropolitan area decreases from industrial, high-density residential commercial, pavement roads, low-density residential commercial, rural residential and vegetation to water. UHI centers (over 20.18°C) are located in main industrial zones. Water has the lowest surface temperature followed by agricultural area, suburban and urban while the built scored the highest surface temperature. Suburbs are heating up much faster than the inner city, due to the construction boom. There has been a steeply rising curve of demand for flats on the outskirts on account of the business boom in Pune. Construction boom, these areas were marked by forests and agricultural farms. Since trees were cut in large numbers and farms disappeared. Due to the infrastructural developmental activity, Highways, new bye-pass roads, were constructed within the city. These newly developed roads facilitate the development of new industrial and settlement area along the sides of these roads and caused the reduction in agricultural area. In the fringes of the city most of the agricultural lands were converted in to settlements. The construction boom resulted in the rapid reduction of green cover. In comparison, the central parts of the city are still filled with old *wadas* and greenery, because of which the rise in temperature has been far more gradual. The 'heating up' of suburban centres in relation to the central parts appear to be changing more subtly. The results showed that urbanisation leads to LULC change and landscape pattern alteration which responded obviously to the urbanisation phases. The loss of agricultural land due to urban expansion in cannot be totally halted, but needs sustainable planning and management in protecting the loss of agricultural land. The data clearly shows that the temperature rose by 2°C in the central parts of the city while in the suburbs it rose by 4 to 10 °C.

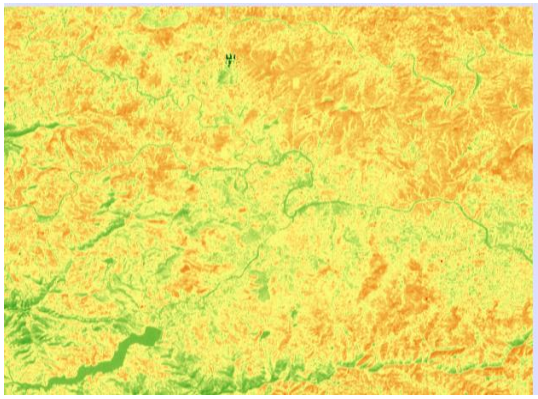

Fig 10: Distribution of surface temperature 1999

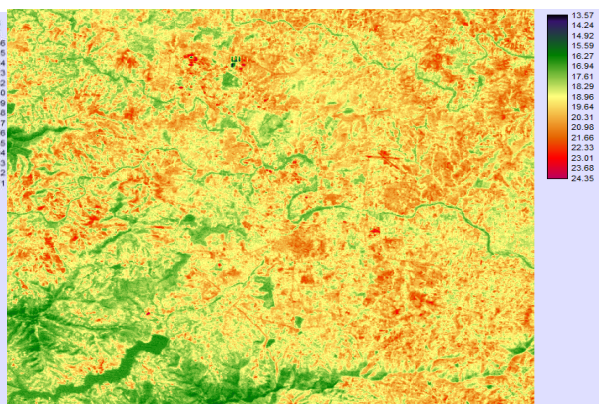

Fig 11: Distribution of surface temperature 2006

It was found that maximum temperatures were recorded over areas with a higher percentage of urbanization/building cover, the opposite was found for areas with a higher percentage of green cover. Of all the land use types studied built-up areas showed the highest average temperatures. UHI centers (over 20.18°C) are located in main industrial zones. Water has the lowest surface temperature followed by agricultural area, suburban and urban while the built scored the highest surface temperature. Since trees were cut in large numbers and farms disappeared. Due to the infrastructural developmental activity, Highways, new bye-pass roads, were constructed within the city. These newly developed roads facilitate the development of new industrial and settlement area along the sides of these roads and caused the reduction in agricultural area. The construction boom resulted in the rapid reduction of green cover. In comparison, the central parts of the city are still filled with old *wadas* and greenery, because of which the rise in temperature has been far more gradual. The data clearly shows that the temperature rose by 2°C in the central parts of the city while in the suburbs it rose by 4 to 10 °C.

IV. CONCLUSION

4.1 Correlation between LULC and UHI Pattern in the Pune

Having seen the general pattern of temperature distribution over the city and having identified the general areas susceptible to the formation of heat island some more areas were studied to find out relationship. There is a low correlation **(**R is 0.26) between Land cover change and Surface temperature (UHI) in case of Pune**.** Reasons for low correlation coefficient in Pune can be- Pune being moderate climate, No Seasonal variation, Limited data of months & time is used for the research, Time studied is morning approximately 9:30-10:30 am, Monsoon effect-Rainfall, Only data of two months is used, need yearly data.

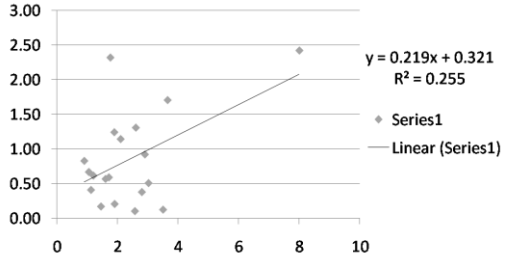

Fig 12: Linear equation & R value

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2} - 2r\left(\frac{S_1}{\sqrt{n_1}}\right)\left(\frac{S_2}{\sqrt{n_2}}\right)}}$$

Where as, $\bar{X}_1$ = average sample1, $\bar{X}_2$ = average sample2, S1 = standard deviation of sample 1, $S2$ = standard deviation of sample 2, S_1^2 = variance of sample 1 , S_2^2 = variance of sample 2, r = correlation between two samples

Fig 13: Formula for T test

4.2 Hypothesis testing-T Test

Here consider two types hypothesis of test are as Ho = there is no influence of land cover LC on the urban heat island LST., H1 = there is an influence of land cover LC on the urban heat island LST. **T – TEST:** t - Stats > t - table Ho is rejected i.e. H1 is accepted t - Stats < t - table Ho is accepted i.e. H1 is rejected**,** With standard error $\alpha = 0.05$. The formula which will be used for two variables are given bellow: Thus by substituting these values in above mentioned formula fig 13 we get

$$t = \frac{(2.17-1.32)}{\{((\sqrt{1.29^2/19}) + (1.39^2/19)) - ((2*0.5)*[(1.29/\sqrt{19})*(1.39/\sqrt{19})])\}} \qquad \mathbf{t = 2.8}$$

$n_1 = n_2$= Sample size or number of samples considered=19, N = overall sample size=n1+n2=19+19=38, df = Calculate the degrees of freedom= N –1=38-1=37. For a given df, 37 if t-value (2.8), is larger than the value in the t table (2.02), the null hypothesis Ho of no difference between the means should be rejected. Thus H1 hypothesis is tested i.e. There is influence of LC on UHI (LST)**.** Thus hypothesis is tested that LULC pattern is related to UHI pattern and is affected by artificial heat sources and variations of surface materials. There is a relationship in change in LC & rise in LST.

V. Acknowledgements

I would like to acknowledge Ar. Poorva Keskar, M.Arch, LEED AP, Pune & Prof. Amit Dhorde, Department Of Geography, Pune University for extending help time to time. Without their support the paper would not have been possible. They encouraged significantly to the work.

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